

THE ISS FLUIDS AND COMBUSTION FACILITY: EXPERIMENT ACCOMMODATIONS SUMMARY

Robert R. Corban
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

ABSTRACT

The ISS Fluids and Combustion Facility (FCF) is in the process of final design and development activities to accommodate a wide range of experiments in the fields of combustion science and fluid physics. The FCF is being designed to provide potential experiments with well defined interfaces that can meet the experimenters requirements, provide the flexibility for on-orbit reconfiguration, and provide the maximum capability within the ISS resources and constraints.

As a multi-disciplined facility, the FCF supports various experiments and scientific objectives, which will be developed in the future and are not completely defined at this time. Since developing experiments to be performed within FCF is a continuous process throughout the FCF's operational lifetime, each individual experiment must determine the best configuration of utilizing facility capabilities and resources with augmentation of specific experiment hardware. Configurations of potential experiments in the FCF has been on-going to better define the FCF interfaces and provide assurances that the FCF design will meet its design requirements.

This paper provides a summary of ISS resources and FCF capabilities, which are available for potential ISS FCF users. Also, to better understand the utilization of the FCF a description of a various experiment layouts and associated operations in the FCF are provided.

FCF OVERVIEW

The ISS Fluids and Combustion Facility (FCF) is one modular, multi-user facility shared by two disciplines. It occupies three powered racks on the International Space Station (ISS) consisting of the Fluids Integrated Rack (FIR), Combustion Integrated Rack (CIR), and Shared Accommodations Rack (SAR). The two disciplines, fluid physics and combustion science, share the three racks and mutually necessary hardware within FCF to dramatically reduce cost and effectively use ISS resources (Figure 1). Owing to the flexibility of FCF, experiments from disciplines outside of fluids and combustion can also be supported.

The FIR features a large user-configurable volume for experiments. The volume resembles a laboratory optics bench. An experiment can be built up on the bench from facility provided packages and user packages. FIR provides data acquisition and control, sensor interfaces, laser and white light sources, advanced imaging capabilities, power, cooling, and various ISS resources. Equipment can be quickly setup by crewmembers and operated from the FCF Telescience

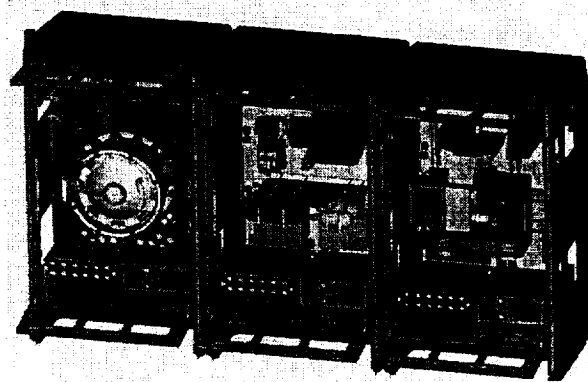


Figure 1 – Fluids and Combustion Facility

Support Center (TSC) or from the Principal Investigator (PI) home institution.

The CIR features a 100-liter combustion chamber surrounded by optical and other diagnostic packages including a gas chromatograph. The CIR can mix on-orbit precise amounts of fuel and oxidizer for the experiment needs. Experiments are conducted in the chamber by remote control from the ground. The CIR is the only rack on ISS dedicated to combustion experimentation.

The SAR contains shared data storage and computational capabilities along with a significant volume and optics bench that is configurable for experiments, similar to the FIR. The SAR provides the ability to maintain the throughput of experiments required by the fluid physics program and allow the CIR to utilize all eight window locations.

The FCF performance requirement stipulates that 10 high-quality, complex fluids and combustion experiments be performed annually within nominal NASA budgetary and ISS resource constraints. It further stipulates that FCF be able to support 80 percent of the fluids and combustion experiments likely to be proposed. Both of these requirements are very difficult to achieve, as well to validate. The FCF project has spent considerable effort in understanding potential

fluid and combustion experiments. This has included developing initial experimental layouts, determining ISS and FCF resources required, and working the the experiment development teams to determine appropriate "grouping" of experiments to minimize the on-orbit hardware required.

ISS RESOURCES

The Fluids and Combustion Facility is being designed to be a permanent facility onboard the U.S. laboratory module, Destiny, of the International Space Station (ISS). Destiny provides an environmentally controlled, pressurized lab environment. Destiny will have interfaces to accommodate the resource requirements of 24 International Space Station Payload Racks (ISPRs). Thirteen of these are research racks and the rest are for controlling ISS systems (Figure 2). The FCF will occupy three contiguous research locations. The ISS supplies the necessary resources to conduct experiments at these rack locations. Resources include power, cooling water, communications, gases, vacuum, exhaust, and command and data handling. Resource allocation will be based on all the activities being conducting on the ISS in the same time frame.

Each of the ISS International Partners (IPs) is allocated a share of Station resources in proportion to their contribution to the program. In addition, bilateral

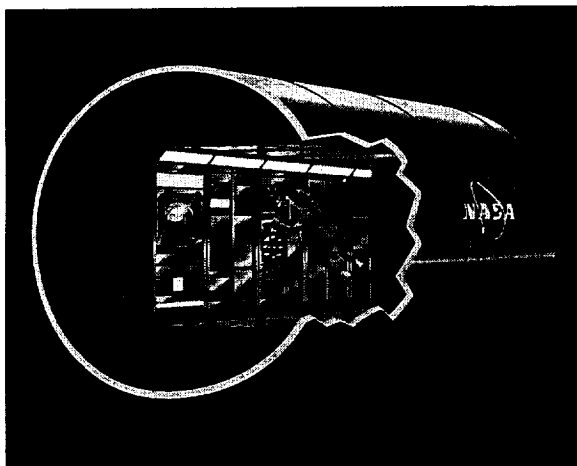


Figure 2 – US Laboratory Destiny

Table 1 – Typical FCF Resources provided by ISS per ISPR (CIR, FIR, SAR)	
Power (typical)	1.5 kW
Power (peak)	3 kW
Resupply Flights	4 per Year
Resupply Upmass	750 kg/yr
Resupply Volume	1.86 m ³ /yr
Return Upmass	750 kg/yr
Return Volume	1.86 m ³ /yr
Cooling H ₂ O	45 – 120 kg/hr @ 18 C
Energy	3200 kW-hrs/yr
On-Orbit Stowage	0.8 m ³ ~1 ISPR
Crew Time	180 hrs/yr
Downlink (typical)	20 GB/day
Microgravity	10 ⁻⁴ g's (w/o ARIS)
Nitrogen gas	< 5 kg/hr
Vacuum Exhaust	276 kPa max

agreements allow IPs and countries to trade resources and responsibilities. Internally, IPs use their own mechanisms to apportion space and research capability to their scientific, technological, and commercial interests.

Allocation of these resources to a specific payload or facility, such as the FCF, is done on an ISS increment basis approximately two years prior to the specific mission. Due to the uncertainty of the allocation of resources, design goals were established in the FCF project (Table 1). The resource allocation goals were implemented to minimize the use, where possible, of all ISS resources. This would allow more opportunities to operate the facility to obtain valuable scientific research data.

Below is a discussion of each major ISS resource and the FCF key design feature in utilizing that resource. An Monte Carlo analysis of the ISS resources by the ISS Program Office based on possible combination of racks to determine the hierarchy of resources. The critical resources were upmass, thermal cooling, stowage, and power. Since crew time was based on a seven members, this resource was not as critical based on the various rack needs.

Power

Station power at assembly complete will be generated from four sets of solar arrays on the Integrated Truss Structure. At assembly complete 26 kW minimum continuous and 30 kW average power and thermal conditioning will be provided to payloads (during Standard and Microgravity modes). An additional 2.5 kW of power is provided to operate ISS systems that support payload operations.

The standard power interfaces for the racks consist of a 3 kW power feed and a 1.2 kW auxiliary feed. The power interface voltage will be approximately 120 Vdc. At 5 selected ISPR locations in the U.S. Lab, a 6 kW power capability is available. At three locations within the U.S. Lab, prime and redundant 6 kW power feeds are provided to support operation of 12 kW payloads.

Electrical power is at a premium on the ISS. The FCF is designed to minimize power usage. The main electrical power converter for the FCF, the Electrical Power Control Unit, utilizes advanced power management techniques to maximize the power available and provide high efficiency power conversion (120 Vdc to 28 V dc at 93% efficiency). The EPCU enables dynamic allocation of power for the two ISS power channels for experiments. Also, the EPCU can provide prioritized load shedding to keep critical scientific experiments to continue and shut down less critical FCF components.

The initial FCF payloads are averaging 1.5kW of power during most science data operations. The FCF has the ability to operate in a low power mode (500 W) for the processing and downlink of data.

Payload Data Handling and Communication

The ISS provides an onboard command and data distribution network associated with a forward and return antenna communication link to transfer research data and video to the payload developer. A 72 kbps S-band forward link is used to send commands for payloads, while a 150 Mbps Ku-band system is used for the payload downlink. Three types of connections are available for this distribution, either directly or indirectly: 1) a MIL-STD-1553B Payload Bus (through a Payload Multiplexer/Demultiplexer), 2) an Ethernet, or 3) a fiber-optic High-Rate Data Link (HRDL). The Assembly Complete orbital coverage for the Ku-band system is approximately 45%. A 216-gigabit communications outage recorder is provided to record research data during loss of signal with the communication system.

The FCF experiments produce a significant amount of digital data that must be returned to the ground via downlink or removable media. The amount of data communicated directly to the ground will be experiment dependent but as a minimum a set of data will be provided to the investigator to permit modification of the test parameters. It is assumed that only 20 GB of FCF data can be downlinked per day based on planned allocations. The range of digital data produced by the initial FCF experiments is from 142

GB to 8 Terabytes, a significant amount of data. The FCF has incorporated removeable, state-of-the-art hard drives and a mass data storage unit. This will allow the FCF operators and researcher to determine the most effective method for the return of scientific data.

Thermal

Thermal radiators are positioned on the Integrated Truss Structure. These radiators are oriented using rotary joints to keep them parallel to the sun's rays so as to keep them from receiving external heat inputs, and to keep them oriented toward space to allow radiation of heat. Using H₂O internally, the radiators pick up heat from the ISS through the environmental control system, which then transfers that heat to the radiators using NH₄ as the active heat transfer fluid.

A moderate-temperature water loop is provided to each ISPR at an inlet temperature range of 16-24 °C (61-75 °F). The water is circulated through FCF's air-to-water heat exchanger and several cold plates to allow thermal conditioning of the internal payload hardware. The maximum return water temperature is 49 °C (120 °F). Only a small amount of heat can dissipate into the cabin air.

The thermal resource is one of the most critical on the ISS. Beyond minimizing the power draw of the facility, the FCF has designed a highly efficient air-to-water heat exchanger to remove the waste heat from the facility. The design of the facility utilizes the optics bench to distribute the air directly to the packages.

Payload Stowage

While the major items of hardware planned for orbital flight on the ISS can be specifically "slotted" at uniquely suitable locations on the vehicle, generic stowage space is required for the small, loose pieces of hardware and consumables that must support a crewed space vehicle. Stowage considerations encompass not just time on orbit, but transport to and from orbit as well. Because stowage is optimized for the entire Station system, instances may result in which research stowage is not immediately adjacent to a User's experiment. The majority of stowage on ISS is provided by ISPR-size racks that are dedicated to

compartmentalized storage. The stowage trays are modular and interchangeable to support a variety of cargo types.

The FCF is designed to be modular and to allow the various modules to be placed in the stowage compartments. The FCF will have in stowage maintenance items, critical ORUs, hard drives, filters, cables, and packages not required for a specific investigation. The investigator will also require stowage to support their investigation that may include gas bottles, filter cartridges, test samples, additional diagnostics, ignitors, and support equipment for sample conditioning or changeout.

Fluids and Gasses Available

Vacuum Exhaust System (Waste Gas).

All of the laboratory modules contain the plumbing to support a waste gas exhaust system that is vented to space. The waste gas system can reach pressures of 1×10^{-3} torr (1.9×10^{-5} psia) in less than two hours for a single payload volume of 100 liters (3.5 ft³) at an initial pressure of 101.4 kPa (14.7 psia). The waste gas system is a shared and scheduled resource that can only be operated at one ISPR location within each module at a time. This requirement is to prevent cross contamination of payloads and incompatible mixtures of waste gas constituents. The types of waste gas constituents allowed must be compatible with the wetted materials of the module waste gas system.

Vacuum Resource.

At selected locations within the U.S. Lab, a vacuum resource line is provided for those payloads requiring a vacuum environment. Each module contains the plumbing to produce this vacuum resource by connection to space. The vacuum is provided at a pressure of 10^{-3} torr (1.9×10^{-5} psia). Multiple payload locations may be connected to the vacuum resource at a time.

Nitrogen.

A nitrogen line is provided as a standard service to all rack locations. The nitrogen is provided between 15.6-45 °C (60-113 °F) at a pressure of 517-827 kPa (75-

120 psia). The flow rates to payloads will be up to 0.9 kg (0.2 lbm) per minute. Each payload will incorporate a valve to control the flow of nitrogen.

Crew Resources

When assembly is complete, the crew will work an 8 hour day Monday through Friday, and a 4-hour day on Saturday. Sundays are planned as crew rest days, although required essential payload maintenance activities, such as care and feeding of biological specimens, will take place. A total of 160 crew-hours per week will be available for research purposes at Assembly Complete. This number assumes the nominal crew size of seven. These hours must be apportioned among all science, technology, and commercial investigations on board the Station. The remaining crew hours will be devoted to Station maintenance, EVA, command and control, and other Station vehicle housekeeping functions as necessary. Additional hours for payload operations may be available, based on the burden of ISS vehicle requirements.

The FCF has been designed to minimize crew time in payload setup, maintenance, and payload operations. The FCF is planning on only utilizing a few hours of crew time per week. The hours available to all payloads on the ISS may also be severely reduced due to a potential of not achieving a planned seven ISS crew. The current complement of three ISS crewmembers may be maintained for an extended period of time that will place a premium on available crew time. The FCF will be able to perform critical investigations on a reduced availability of crew time but may require longer on-orbit experiment durations.

FLUID EXPERIMENTS

The Microgravity Fluid Physics program currently has four major research thrust areas: Complex Fluids, Interfacial Phenomena, Dynamics and Instabilities, and Multiphase Flows and Phase Change. There are currently more than 140 ground-based and 20 flight/flight definition investigators conducting experimental research. Complex Fluids includes colloids, foams, granular media, rheology of non-Newtonian fluids, and emulsions and suspensions.

Interfacial Phenomena includes liquid-vapor interface configurations, contact line dynamics, capillary driven flows and shape stability and break-up of liquid bridges and drops. Dynamics and Instabilities includes thermocapillary and thermosolutal flows, bio-fluid mechanics, geological fluid flows, pattern formation, and electro-kinetics and electro-chemistry. Multiphase Flows and Phase Change includes flow patterns in liquid-vapor/gas flows in microgravity, nucleate boiling and its control using acoustic and electric fields in microgravity, and flows of gas-solid and liquid-solid mixtures in microgravity.

To minimize the quantity of hardware required to implement these experiments, selected early experiments have been grouped to permit development of multi-user modules, which fit within the FIR and take full advantage of its capabilities. The first three multi-user modules consists of the Light Microscopy Module, Granular Flow Module, and the Pool Boiling Module.

Light Microscopy Module

The first multi-user module is the Light Microscopy Module (LMM), Figure 3. LMM is a self-contained microscope which offers microscopy, sample changeout and fluid containment capabilities, and an array of optical diagnostics. These optical diagnostics consist of: various kinds of microscopy (bright field, dark field, phase contrast, differential interference contrast,

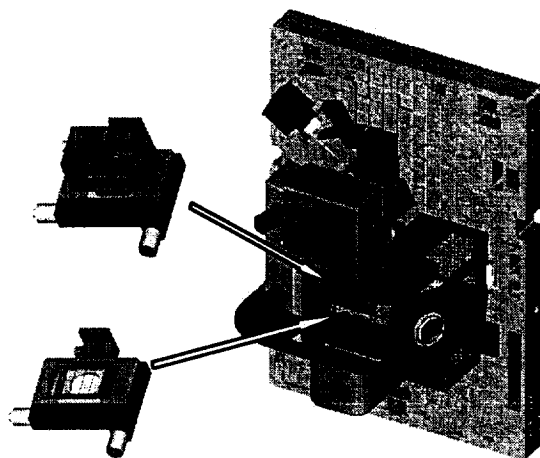


Figure 3 – Light Microscopy Module

confocal, and fluorescence); various kinds of light scattering (static, dynamic, and Bragg); and specialized optical features (laser tweezers, spectroscopy, and interferometry).

The Light Microscopy Module (LMM) is key example of automation that will be utilized on the FCF to minimize use of crew time. LMM is a remotely controllable (Telescience) on-orbit microscope subrack payload, allowing flexible scheduling and control of physical science and biological science experiments. The LMM is a modified commercial research imaging light microscope with powerful laser-diagnostic hardware and interfaces, creating a one-of-a-kind, state-of-the-art microscopic research facility. LMM has many of its features automated, such as high-resolution color video microscopy, brightfield, darkfield, phase contrast, differential interference contrast, spectrophotometry, confocal microscopy and laser tweezers. The LMM also provides an enclosed glovebox with gloveports for transporting experiment samples into the microscopy by the ISS crew. The LMM is an excellent blend of automation, telescience and critical crew interfaces for providing an optimized research environment for the principal investigators.

There are four initial investigations which will be using LMM in the FIR:

Constrained Vapor Bubble (CVB) experiment - CVB will study vapor bubbles pertinent to the understanding of heat pipes and heat transfer mechanisms. The experiment will improve our understanding of the heat and mass transport mechanisms that are controlled by the interfacial phenomena. Specific objectives are: to determine the overall stability of the device; to study flow characteristics; to determine average heat transfer coefficients in the evaporative and condensing parts of the CVB; and to determine these transfer coefficients as functions of void fraction and heat transfer rates.

Physics of Colloids in Space-2 (PCS-2) - PCS-2 will study the nucleation, growth, morphology and coarsening of crystal structures as well as rheological properties. Three general classes of samples are planned: binary hard sphere alloys (highly ordered), colloid polymer mixtures, and fractal aggregates.

Physics of Hard Spheres Experiment-2 (PHaSE-2) - PHaSE-2 will study nucleation, growth, rheological properties and morphology of crystal structures in the context of hard sphere colloidal suspensions. The intent is to create novel structures, to study the dynamics of their formation, and their phase transitions in order to differentiate kinetic and equilibrium structures.

Low Volume Fraction Entropically Driven Colloidal Assembly (LΦCA) - This experiment will study the nucleation and growth of surface crystal structures from colloidal suspensions. The study will focus on low-volume-fraction particle suspensions of unagglomerated spheres having small diameters so that thermodynamically driven Brownian motion maintains the suspension. These entropically-driven crystallization experiments will explore the creation of new colloidal structures of potential industrial importance (e.g., photonic band-gap crystals). By eliminating particle sedimentation effects, microgravity creates a purely "thermodynamic" environment for the suspensions where particle size, volume fraction and interparticle interactions are the primary determinants of the resulting structures.

Granular Flow Module (GFM)

A second multi-user module is the Granular Flow Module (GFM). It will be designed to conduct several experiments utilizing granular media – the first two of which are described below (Figure 4).

Microgravity Segregation of Energetic Grains (μgSEG) - The primary goal of μgSEG is to induce and maintain particle segregation in a collisional flow of two different types of spheres. In the absence of gravity, segregation will be driven by a gradient in the kinetic energy of the mixture which is produced in a closed loop, annular shear cell. The inner and outer walls of the shear cell provide moving boundaries which are rotated at different speeds.

Particle Interactions in μg Flow Cell - The main objective is to study the interaction between a flowing gas with relatively massive particles (constant diameter spheres) that collide with each other and with the

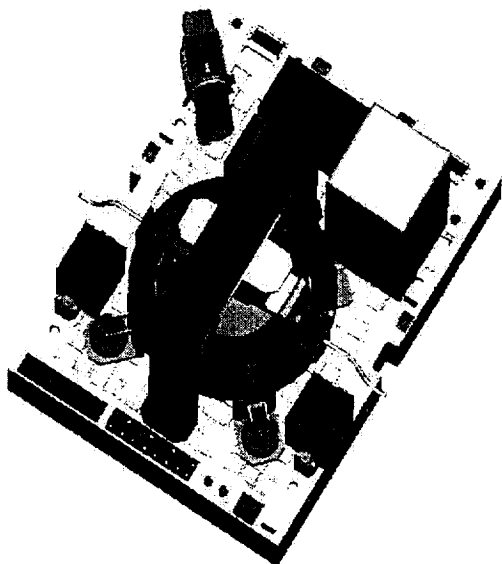


Figure 4 – Granular Flow Module

moving boundaries of the cell. Over the range of non-turbulent flow conditions, the objectives are to characterize the viscous dissipation of the energy of the particle fluctuations, to measure the influence of particle-phase viscosity on the pressure drop along the cell and to observe the development of localized inhomogeneities likely to be associated with the onset of clusters. The cell, expected to be essentially the same as for the above experiment, has annular geometry with bumpy frictional boundaries to control the energy of particular fluctuations.

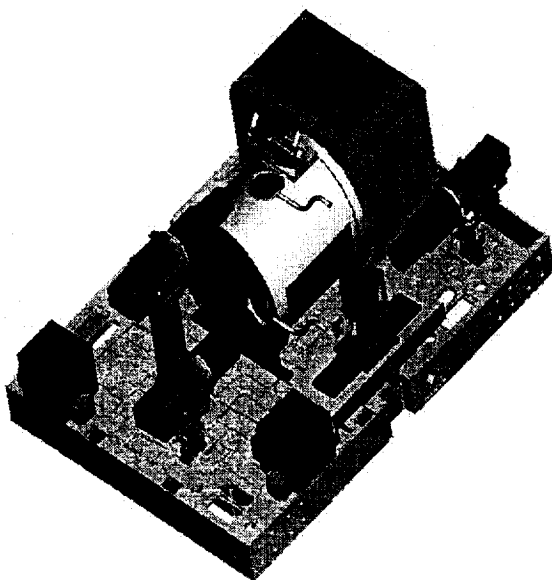


Figure 5 – Pool Boiling Module

Pool Boiling Module (PBM)

A third multi-user facility is the Pool Boiling Module (PBM). It will be designed to conduct pool boiling experiments – one of which is described below.

Nucleate Boiling in Microgravity - The proposed study will provide basic knowledge of the phenomena (e.g., heat transfer and vapor generation and removal processes during nucleate boiling conditions) that enables the development of simulation models and correlations used in the design of space- and Earth-based boiling systems (Figure 5).

COMBUSTION EXPERIMENTS

The Fluids and Combustion Facility (FCF) will support extensive study of combustion in microgravity utilizing the Combustion Integrated Rack. The combustion experiments that may be conducted in the FCF include: the study of laminar flames, reaction kinetics, droplet and spray combustion, flame spread, fire and fire suppressants, condensed phase organic fuel combustion, turbulent combustion, soot and polycyclic aromatic hydrocarbons, and flame-synthesized materials. The facility will provide most of the capability with a small amount of unique hardware developed for each investigation and, when possible, similar investigations will be flown at the same time to increase the use of common hardware and diagnostics.

To further reduce hardware requirements, an initial set of three multi-user chamber inserts is being designed. The inserts will, to the greatest extent possible, include experiment-specific hardware needed for a class of investigations. A total of fourteen flight and flight-definition investigations supported by the NASA Microgravity Science Program and one or more commercial investigations are currently foreseen to use the CIR over the first few years of operation. The first three multi-user modules for the CIR consists of the Multi-user Droplet Combustion apparatus (MDCA), Solid Fuels Apparatus, and a Gaseous Fuel Apparatus.

Multi-user Droplet Combustion Apparatus (MDCA)

The first multi-user module is the Multi-user Droplet Combustion Apparatus (MDCA), Figure 6. Four investigations are being planned for MDCA to study the

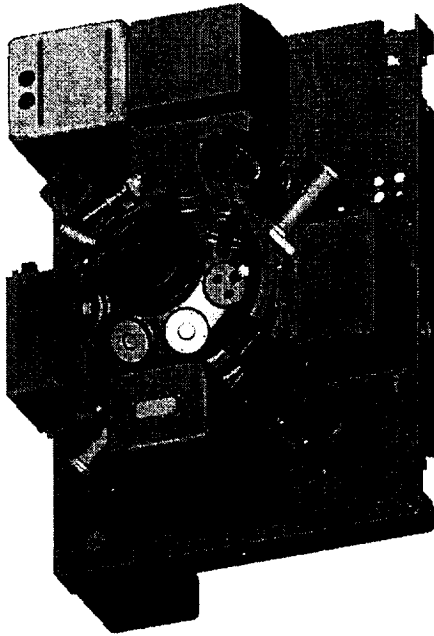


Figure 6 – MDCA Setup (DCE-2)

combustion of small droplets of pure and bi-component alcohol and hydrocarbon fuels. Liquid fuels are a primary source for energy production in the world and the study of their combustion has been ongoing for decades. MDCA will provide an insert that contains the droplet deployment mechanisms, hot-wire igniters, a fuel supply system, and a gas-mixing fan. The insert structure is open to permit viewing of the droplet and flame.

MDCA utilizes a modular approach to accommodate PI specific requirement needs. The insert has replaceable on-orbit components to reduce upmass requirements and is designed to operate from the ground with little crew involvement. Many of the diagnostics can be utilized and/or reconfigured to meet the needs of the individual experiments to minimize upmass requirements.

There are four initial investigations which will be using MDCA in the CIR:

Droplet Combustion Experiment (DCE-2) – This experiment is a reflight of an experiment previously flown on the Space Shuttle (DCE-1). The primary goal of DCE-2 is to better understand combustion kinetics of droplet burning history (transient & quasi-steady), radiative heat loss, and extinction phenomena.

Bi-Component Droplet Combustion Experiment (BCDCE) – The main goal of BCDCE is to study bi-component fuel droplets where spherical symmetry is approached in the gas and liquid phases to understand transient behaviors between the liquid & gas interfaces.

Sooting Effects in Droplet Combustion (SEDC) Experiment – The key objective of SEDC is to better understand the effects of sooting and radiation influences on the overall burning behavior of droplets by means of optical and intrusive techniques.

Dynamics of Droplet Combustion & Extinction (DDCE) experiment – This experiment will investigate the effects of small convective flows on burning droplets and better define the influences of such flows on the extinction process.

Solid Fuels Apparatus

A second multi-user module is a apparatus for investigation of solid fuels. Six investigations are currently planned for this combustion area of study using small solid fuel samples. Such studies are important for the development of improved material flammability tests and predictions, and for development of improved modeling of ignition, spread, and extinction of flames in solid materials. Enhanced fire prevention on the Earth and in spacecraft are potential

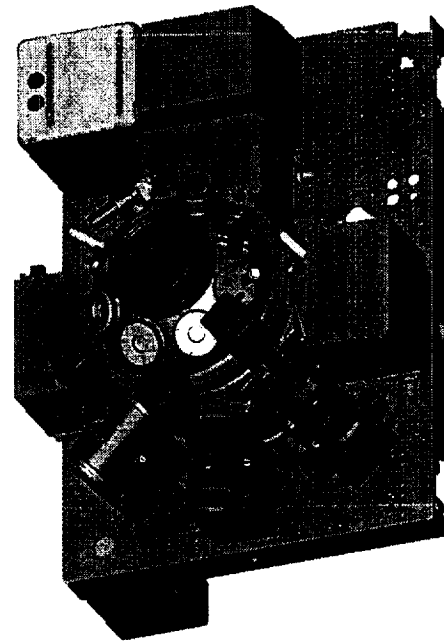


Figure 7 – Solid Fuels Apparatus Setup

benefits of this research. Most of the investigations require a sample holder, a flow duct to provide a low speed convective flow environment, an ignition system, and a clear volume for imaging of the flame and solid fuel surface (Figure 7)

Gaseous Fuel Apparatus

A third multi-user module is a gaseous fuel apparatus. Six investigations are currently planned for the study of various types of gaseous fuel combustion. Premixed and non-premixed gaseous combustion using nozzles of various sizes, flame vessels and tubes, and porous spherical burners will be studied. Gaseous combustion occurs in many practical systems as well as in unwanted fires. The use of gaseous fuels simplifies the study of the main processes in combustion, chemical reaction and heat and mass transfer. For as many experiments as possible, the hardware insert will be based upon the chamber insert developed for the Laminar Soot Processes experiment previously flown in the shuttle-based Combustion Module. Most of the investigations will require a small fuel nozzle with a hot wire igniter, a far-field thermocouple rake, a flame radiometer, and thermophoretic soot samplers (Fig. 8)

OPERATIONS

Unlike previous U.S. space vehicles, the ISS will operate continuously over several years, and will allow change-out and upgrade of payloads during that time. Planning for payload operations will allow new payloads to be added or permit the return of on-orbit payloads as part of the normal change process. The FCF is being designed to take advantage of these continuous ISS operations with maximum use of autonomous, ground-tended operations. The FCF is being designed for quick and easy setup and reconfiguration. Typically, once an experiment is set up by the crew, it will be operated from the ground. Experiment progress will be monitored by the operations support team and will routinely uplink commands based on experiment protocol. FCF payload operations will include a broad range of automated, crew-attended, unattended, and telescience operations.

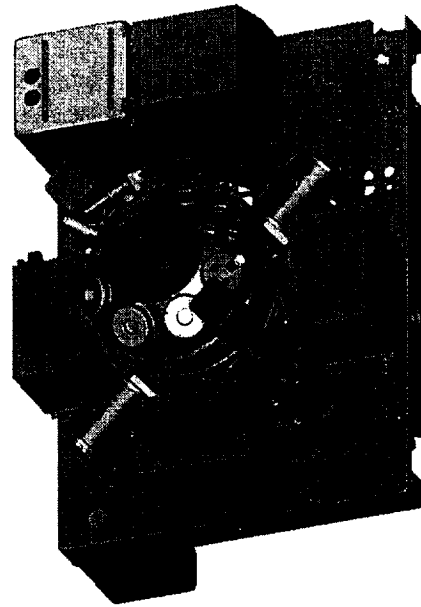


Figure 8 – Gaseous Fuel Apparatus Setup

Automation

The FCF has taken significant advantage of both automation and telescience operations in its planning and design. The FCF has designed many crew interfaces to enable quick experiment setups and reconfigurations allowing more time and resources for obtaining scientific data. These design features have been worked with veteran astronauts and potential ISS crew members to validate the designs and provide valuable feedback to the designers on better features to allow the ISS crew to efficiently configure the FCF researcher's hardware. Automation of many of the features of the FCF, such as automated tracking of science phenomenon, imaging controls (focus, aperture, position, timing), scripted experiment operations, blending of experiment gases, processing and compression of images, variable illumination outputs, gas analysis, and variable spectrum filtering provide a ISS facility that takes advantage of automation to minimize crew time in the operation of the experiment.

Crew Tended

The FCF will require the ISS crew to perform key operational tasks to perform the various experiments. These crew tended operations will consist of: install the initial launch of the FCF, install the Active Rack Isolation system, setup the experiment, perform initial

alignments of some diagnostic packages, replace data storage devices (i.e., hard drives), replace test samples, clean components (optics, chamber, etc.), assist in on-orbit verification and checkout, assist in resolution of hardware problems, remove completed experiments and prepare equipment for return to the ground.

Maintenance

The FCF will require periodic maintenance during its 10 year mission life. With a proper maintenance program the FCF can extend its useful life beyond the ten years, if necessary. The maintenance activities will consist of lint filter change-out, inspection for fluid leaks, replacement of sensors, calibration of sensors, CIR absorber cartridge and bottle change-out, and ORU replacement (base on reliability predictions). The FCF will have a set of spares that will be located on the ground, as well as a few critical spares stowed on-orbit. The quantity and location of the spares will be determined based on hardware reliability data and failure predictions.

Telescience

"Telescience" is defined as the acquisition of information through remote experimentation and observation. Telescience will maximize the ability of researchers to communicate with the crew, to direct the "commanding" of their research hardware and software, and to manage the receipt, processing, and analysis of their research data, from laboratory desktop computers.

The FCF takes advantage of telescience operations in providing the researcher with the ability to modify experiment parameters based on previous data obtained similar to laboratory operations performed on Earth. For the first time in space research, scientists will be the primary operators of their payloads. The telescience operations allows the FCF to perform calibrations, maintenance activities, experiment scripts, software updates, and data analysis by the principal investigator.

Glenn's newly renovated Telescience Support Center (TSC) provides the capabilities to execute ground support operations of on-orbit space station and space shuttle payloads. The Glenn TSC will be the hub for FCF operations. The FCF users can either locate their

operations staff at Glenn or request a convenient location, such as the researcher's home university.

Summary

The International Space Station will provide researchers an exciting opportunity to perform investigations into the fundamentals of science. The ISS provides a unique opportunity for many areas of research along with operating a space flight vehicle to support manned operations. The ISS resources will be in great demand by all of the facilities and ISS systems to take advantage of this unique long duration research platform. Facilities that have designed to require minimum ISS resources to operate will have the most opportunities to perform their unique science and technology investigations. The Fluids and Combustion Facility has been designed from the beginning with this constraint to maximize the opportunities for the science payloads. Current challenges in the ISS Program have put increased risk that anticipated resources may be lower than currently planned due to smaller crew sizes and reduced ISS capabilities. If these current risks become reality, facilities that have been designed to minimize their need for ISS resources will be able to continue a successful science program. The FCF has taken those risks into account with automation, efficient power utilization, data handling options, quick reconfiguration mechanisms, telescience operations, multi-user payloads, and numerous uses of advanced technology. The FCF provides the researcher an excellent opportunity to develop the fundamental knowledge and solutions for tomorrow's engineering challenges.

Acknowledgements

The development of the Fluids and Combustion Facility is possible with funding from the NASA Office of Space Flight and the NASA Office of Biological and Physical Research. The author also acknowledges the dedication and many innovative contributions to the success of the FCF by the NASA Project team, Northrup Grumman, Analex Corporation, and Hamilton Standard. Without the support of the dedicated development team to solve complicated problems and the infusion of new ideas to maximize the FCF

capabilities, the breadth of fluid physics and combustion science experiments that could be performed with limited ISS resources would be limited at best.

References

1. O'Malley, T. and Weiland, K., "The Fluids and Combustion Facility Combustion Integrated Rack: Microgravity Combustion Science on Board the International Space Station," AIAA-2001-4927, Conference & Exhibit on International Space Station Utilization, Kennedy Space Center, Fl., October 2001.
2. Zurawski, R., "The ISS Fluids and Combustion Facility: Microgravity Combustion Science and Fluid Physics Research Capability," AIAA-2001-4925, Conference & Exhibit on International Space Station Utilization, Kennedy Space Center, Fl., October 2001.
3. Gati, F. and Hill, M., "The FCF Fluids Integrated Rack: Microgravity Fluid Physics on Board the ISS," AIAA-2001-4926, Conference & Exhibit on International Space Station Utilization, Kennedy Space Center, Fl., October 2001.
4. Fox, D. and Poljak, M., "A Unique Power System for the ISS Fluids and Combustion Facility," AIAA-2001-5017, Conference & Exhibit on International Space Station Utilization, Kennedy Space Center, Fl., October 2001.
5. Lauver, R., Kohl, F., Weiland, K., Zurawski, R., Hill, M., and Corban, R., "Microgravity Combustion Science and Fluid Physics Experiments and Facilities for the ISS," Spacebound 2000, Vancouver, BC, Canada, May 2000.
6. Motil, S., Snead, J., "The Light Microscopy Module: An on-Orbit Multi-User Microscope Facility," AIAA-2001-4956, Conference & Exhibit on International Space Station Utilization, Kennedy Space Center, Fl., October 2001.
7. The International Space Station User's Guide – Release 1, Space Station Program Office, Houston, TX, September 1999.